

Comments on

“High-resolution automated detection of headwater streambeds for large watersheds”

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The paper presents different algorithms to automatically detect headwater streambeds from LiDAR DEMs for large watersheds in the province of Quebec, Canada. There is clearly a need to improve the detection of these small headwater streams. Overall, however, I felt that the methodology presented in this study would benefit from being explained in a clearer and more structured way, perhaps with an additional figure to clarify the different steps. The PROB model, in particular, needs to be better described (see detailed comments).

The authors often refer to surface and subsurface processes, with D8 and PROB models representing the surface processes and TPI (topographic position index) the subsurface processes. It is not entirely clear what the role of subsurface processes is in the geomorphological contexts studied here (see detailed comments) and how TPI can account for these subsurface processes, “where the water table plays an important role in the initiation of streambed” (line 477). As stated on p. 14, “The scale at which this variable is calculated strongly influences the morphometric feature that is identified. When the scale is large, the variable will tend to identify valleys, while it tends towards streambeds when the scale is small (Montgomery and Dietrich, 1992, 1994). For the purposes of this paper, a relatively small scale of 6 to 30 m was used.”

In summary, I believe the paper presents a useful analysis of headwater streambed detection, but that major revisions are needed to clarify the methodology and make sure the link with hydrological processes is based on more convincing evidence.

Detailed comments

p. 2, lines 15-17: I don't think it is necessary to define streambed or channel head in the abstract. I suggest deleting the first two sentences and starting the abstract with “Headwater streams...”.

p. 2, line 25: It is not clear what “Homogeneous hydrological processes” means.

p. 2, line 28: Can you really say that the algorithms developed in this study “recreate the surface runoff process”, or that “an iterative process” “recreates water diffusion” (line 31)?

p. 3, line 40: I don't understand the “mostly” in this sentence. Aren't streams formed (entirely) by fluvial processes? As with the abstract, I suggest deleting the first two sentences of the Introduction, as the definition of streambeds is well known.

p. 3, lines 56-60: It would be useful to clarify if the underestimation of headwater streams in the GRHQ database is common in other, more widely used, database such as the NHD (National Hydrography Dataset) – see for example Hafen et al. (2020).

p. 4, line 75: Define acronym LiDAR.

p. 4, lines 75-87: This could be summarized in only a few sentences.

p. 5, lines 87-89: Are you still talking about LiDAR DEMs here? Montgomery and Foufloula-Georgiou (1993) worked on a 30-m DEM, not LiDAR, and Henkle et al. (2011) and Elmore et al. (2013) worked from 10-m National Elevation Data DEM.

p. 5, line 91: streambed (instead of bed) formation.

p. 5, line 99: Not entirely clear what the “geomorphological level” means. Also not clear what you mean by “such as large validation database” since you have not mentioned validation database before.

p. 5, line 104: It is the first time you mention anthropization. It would be useful to clarify in the previous paragraphs of the Introduction why this affects the detection of headwater streams (and cite a few references about this).

p. 6, line 112: It is not clear what you mean by “general description” in this context.

p. 6, line 113: It would be useful to give examples of differences in hydrological processes as this sentence is not entirely clear.

p. 6, line 115: It would be useful to provide information on the average slope for hillslopes in the studied watersheds.

p. 8, line 146 (Figure 1): This figure could be improved, adding a legend to clarify what the red polygons represent (watersheds?) and adding a few labels for the main cities (e.g. Montreal), with also a label for the province of Ontario.

p. 9, line 175: software (instead of software’s)

p. 10, lines 200-206: References on subsurface processes for streambed formation, and particularly their higher rate of incision, are needed as this explanation is not clear. Subsurface flow will affect the extent of contributing areas (saturated overland flow) and hysteresis (Jensen et al., 2019), but the link between these hydrological processes and streambed incision is not obvious. Channel incision, as noted by Wohl (2018), is more prevalent in arid to semiarid environments, or in karstic landscapes, which is not the geomorphological context of this study.

p. 11, lines 209-211: This is not obvious in the context of this study (see above comment).

p. 12, line 229 (Table 1): It is not clear why anthropogenic land is considered in the same category as glacial moraines and fluvial deposits (thick soil with high infiltration rates). Roads

and urbanized areas, for example, clearly don't have high infiltration rates (nor thick soils). Also, is it always the case that organic deposits have low infiltration rate?

p. 13, line 238: By "geospatial line", you mean a vector line feature?

p. 13, line 244: What is the elevation error in the LiDAR datasets used in this study?

p. 13, lines 253-254: "The elevation errors therefore had a standard deviation of 0.08 m, randomly distributed over the DEM." It is not clear where the value of 0.08 m comes from. Is this based on the LiDAR accuracy or was this value determined by the authors (if so, how)? Since you conclude that "the variable PROB, which describes the probability of occurrence of a streambed, was used to correct errors associated with the positioning of streambeds" (line 528), it is important for the reader to fully understand this PROB variable which, unlike D8 or TPI, is not a well-known variable. The paragraph starting at line 240 is not sufficiently clear.

p. 14, line 260: "This PROB variable revealed the diffusion process of the water in hillsides, where the slope is relatively uniform." This sentence is not clear and, as mentioned above, it would be useful to provide more information on slope in your study areas (why is slope considered relatively uniform?).

p. 15, line 288: "...a bed was considered to be present when natural fluvial processes allow it to be maintained." Can you clarify what criteria were used to determine when natural fluvial processes allowed to maintain a streambed?

p. 15, line 289: I find the definition of these "geospatial lines" confusing. Were they an output of your analysis? See my previous comment (line 238) where you defined "geospatial lines" as "a real stream" represented in the database.

p. 15, line 298: Lessard (2020) is a Master's thesis (in French). Are there more accessible, peer-reviewed references about this threshold of 0.11 ha?

p. 15, line 302: Confusing units (1100 m²) – this was given in ha on line 298. Overall, it is not straightforward to follow the methodology used in this study to identify headwater streams. Perhaps a summary figure could be provided to clearly indicate the various steps?

p. 18, line 340: "This model was called CART". Delete since this is already mentioned on line 339.

p. 18, line 342: Clarify what you mean by "homogeneous hydrologic processes". Do you mean the 3 hydrological classes described in Table 1 (shallow soil, thick soil with high/low infiltration rates)? There seems to be a confusion in the use of "processes" and "classes", particularly since one of these classes (thick soil with high infiltration rates) includes anthropogenic land where processes are likely different from those in, say, forested watersheds.

p. 18, line 353: Replace "over a known territory of" with "over an area of".

- p. 19, line 360 (Figure 3): The font size for X axis labels should be reduced.
- p. 19, line 366: Remove “located in the entire surveyed area” as it is implicit.
- p. 20, line 384 (Figure 4): Explain the colour scheme in the caption.
- p. 21, line 397: Be consistent with upper- or lower-case for kappa.
- p. 22, line 422: Were you able to distinguish between highly anthropized areas and more natural areas?
- p. 25, line 476-478: What about the urbanized areas that are included in this category (see comments above on Table 1)?
- p. 25, lines 481-482: I am still not convinced that you have shown sufficient evidence that in the geomorphological context you are studying, channel heads are formed “by gully processes where groundwater intersects the ground surface (Dietrich and Dunne, 1993; Wohl, 2018).” The gullies that are described in Dietrich and Dunne (1993) – for example their Fig. 7.24 in northern Tanzania – are really very different from the geomorphological context of this study with thick soils and (often) a vegetation cover. Also, Wohl (2018) stated “Subsurface flow commonly dominates hillslopes with full vegetative cover and thick soils (Dunne and Black, 1970a). Infiltrating water that remains in the subsurface can flow downslope in the unsaturated zone above the water table as throughflow, or in the saturated zone below the water table as ground water. In either case, subsurface water flowing through small interconnected pores will have low velocity, laminar flow (Kampf and Mirus, 2013).”
- p. 28, lines 544-546: This sentence needs to be improved (...developments... will not be improve...).

References

Hafen, K.C.; Blasch, K.W.; Rea, A.; Sando, R.; Gessler, P.E. (2020) The influence of climate variability on the accuracy of NHD perennial and nonperennial stream classifications. *J. Am. Water Resour. Assoc.*, 56, 903–916